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Inside

Water-Resistant Barriers

From the Editor ...

We love to whine and grumble about rules, regulations and how they are administered. Often there is a slow, creeping growth in what we refer to as red tape until it seems to have become an insurmountable obstacle to human progress, or at least an obstacle to do whatever it is we may be restricted from doing.

From time to time there needs to be a review to ensure that the purpose behind a given regulation is still current and there is still a need for it. When regulations become so cumbersome that individuals chafe and find ways of working around them, we see a growth in side deals. We see it in many parts of the world, both in industrialized or so-called underdeveloped nations. We see it in Canada, in the way rules and regulations are benignly overlooked until something happens and there is a crackdown, or as a form of protest such as "work to rule" job actions. We also see it in the growth of what is referred to as the underground economy.

However, we need to recognize that most regulations and administrative steps are created to protect society. They set out minimum standards and provide a mechanism to make sure they are followed. Just like the police do in keeping order in our communities. Like it or not, we need to have a functioning policing system. That is what quality assurance procedures in manufacturing plants do. On the construction job site, that is what site supervisors, professionals and inspectors do. Checks and balances are important, since no one is perfect.

When a regulatory review is done, it must be done fairly and honestly. Unfortunately, sometimes these reviews get carried away. That is what seems to have happened in BC. At the outset of its mandate four years ago, the current government set out to reduce red tape by one third. This number was arbitrary and the fervour with which the quota was established and pursued throughout the government looked too much like the goals of the Soviet five-year plans of another era.

The unstated premise, it seems, was a philosophical belief that government is bad; that government can do nothing right, and the private sector can do nothing wrong. The quota-based regulatory reform led to the absurdity of someone having to calculate that the Building Code represented some 10,000+ regulations. I don't think anyone stopped to consider which third of the building code was to be cut out in order to meet the arbitrary regulatory cutback quota.

Many other rules, regulations and administrative changes have also been made. Many are only about to be implemented. From what I've heard so far, they will drastically change the way business is to be done in BC – but I don't think it will be for the better. In fact, they will probably affect community health and safety, oversight of which is a key function of government.

One of the changes is that the BC Ministry of Health will no longer be involved with the permitting or inspection of small on-site sewage systems, such as septic systems. The whole process will now be handled by industry. Training for the industry is being developed, but basically this means that it will be left to the good will and honesty of everyone affected to ensure proper system design, installation and operation, without any third party oversight. How well this will work is to be seen. (Isn't there a saying about the fox guarding the henhouse?)

Another change that has serious safety consequences is to the gas appliance permitting procedures. The system has been modified so that now even a homeowner is entitled to do their own gas appliance installation. Although there is supposed to be a mechanism that will flag jobs by amateurs for scrutiny, no building official I've talked to is comfortable with how well the new system will work.

If we forget that the fundamental reason for regulations, permits and inspections is to ensure health and safety in the community, we do so at our peril. Independent, impartial third party reviews are a key function of government agencies. Privatizing the whole system is fraught with danger, not the least because of the lack of accountability and the possibility for conflicts of interest.

Richard Kadulski,
Editor

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Water-Resistant Barriers

Recent building envelope failures of face-sealed claddings, especially Portland cement stucco in the lower mainland of British Columbia and exterior insulation finish systems (EIFS) in North Carolina, have highlighted the importance of doing proper details to control rain penetration.

What is often overlooked is that sheathing membranes play a critical role in managing moisture that penetrates the exterior cladding. As a class of materials, they are sometimes referred to as a water- (or weather-) resistive barrier.

The sheathing membranes are also important in controlling vapour movement and air infiltration and exfiltration. However, there has been relatively little research into their performance, and product standards primarily deal with product manufacturing processes and quality assurance. Spurred on by the questions raised during the research work concerning the building envelope failures in BC, CMHC along with industry partners formed an external research consortium at Montréal's Concordia University. The objective was to study the moisture performance of water-resistant barrier materials.

The research set out to:

- develop a material classification system,
- review laboratory test methods for reviewing properties of water-resistant barrier (WRB) products,
- examine various effects on water-resistant barrier performance, including the effects of:
- various substrates on moisture transfer through selected WRB products
- various boundary conditions,
- outdoor weathering on WRB properties, such as water head,
- various extractives and surfactants,
- weathering on WRB properties,
- fastener penetration on moisture transmission into substrates.
- develop a performance-oriented test method to more realistically describe WRB products.

There are many specialized membrane products with properties tailored to various applications. Those intended for WRB applications vary in the way they are manufactured and in the raw materials from which they are made. The research group developed a classification system for WRB products.

Class C

Asphalt-impregnated cellulose fibre WRB. These include felts and commonly-used building papers. The asphalt material imparts water resistance to the cellulose fibres.

Class P

Polymeric fibrous WRB. These include sheet materials manufactured from spun-bonded polyolefin fibres that are hydrophobic and form a mat that repels water.

Class PP

Perforated polymeric film. These sheet materials are monolithic poly films that are mechanically perforated to permit vapour to pass and to provide some resistance to water penetration.

Class M

Micro-porous film WRB. These sheet materials are monolithic poly films that have particles incorporated into the material. When the film is stretched, some of the particles fall away, leaving a film with micro-pores.

Class LA

Liquid-applied (by spray or trowel) WRB. These films are formed by applying one or two coats of a liquid base-coat material to wood-based or gypsum-based sheathing. When cured, the films provide a water-resistive coating on the sheathing and at joints.

Most of the research was focused on representative samples of Class C and Class P materials. This reflects that these are the most widely-used WRB products. However, all classes, except the micro-porous films, were included in the research.

Existing test methods

The paper, textile and polymer industries have developed a number of test methods to

evaluate membrane products for WRB applications, but their primary purpose is quality control. These include the "boat test," the "dry indicator test," the "ponding test" and the "hydrostatic pressure test." Each test checks certain abilities of WRB to repel or prevent moisture from passing through the material.

The boat test makes a small boat of the material, placing a powder that changes colour when it becomes wet inside the boat, and floating the boat. The time taken for the colour to change is a measure of the material's resistance to passing moisture.

The dry indicator test is a modification of the boat test. The experimental setup consists of an aluminium float or a hollow cylinder with a wire frame clamp for mounting the specimen and a watch glass. The test specimen's lower surface is exposed to water and the time required for moisture to pass through the specimen, as indicated by the colour change of the moisture indicator on the specimen's upper surface is measured.

For the ponding test, a 25 mm (1 inch) head of water is placed on the membrane and researchers measure how long it takes for three drops of water to pass through.

For the hydrostatic pressure test, high water heads are applied against the membrane to determine the pressure needed to overcome the surface tension of water in the pores to allow flow to take place through them.

Water flow has been the dominant consideration and vapour flow a secondary consideration. Some materials appear to perform better in one type of test than another. None of the tests provides direct information about how these materials perform in a wall assembly. As a result of these comparisons, the consortium felt that more fundamental measurements were necessary to better understand how WRB materials function to protect walls.

Existing and new test methods

One test method used to obtain the fundamental properties of membranes is the ASTM E96 "dry cup" and "wet cup" test. The dry cup test exposes the membrane to a differential relative humidity (RH) of 50 percent and measures the weight gain in a desiccant used to establish the low RH (near zero percent). This provides a measure of the water vapour flow through the material. For the wet cup test, water is placed inside the cup instead of desiccant and an RH of 50 percent is maintained on the outer face of the sample. The weight loss of moisture from the assembly is measured.

For the "inverted cup test," a known amount of water is placed on top of the membrane in a test cup and the change in weight is measured as moisture escapes by diffusion through the membrane. Usually, the RH applied on the "dry" side is 50 percent. This test appears to be intuitively correct for assessing vapour flow.

Having the top surface exposed to an inch or so of water, with the bottom surface exposed to a known dry environment, such as that provided by a conditioned space or by a desiccant, provides very well-defined boundary conditions. Under these conditions, the highest possible driving force is created for the diffusion of water vapour through the material. Testing showed that the effect of moderately higher water heads did not significantly affect the results. It showed a constant rate of moisture transfer over time.

When a building material is used as the moisture sink instead of a desiccant, the test becomes an assessment of an assembly or a composite. For example, when the membrane is placed directly over OSB, plywood, gypsum or other sheathing material, the ability of moisture to move through both the membrane and the substrate is a measure of the resistance of the assembly, not just the membrane. This reflects the actual use of membranes. While the test cannot be used to obtain fundamental properties directly, it is a useful way to examine order-of-magnitude effects involving penetrations and some other physical parameters. This test method has been designated as a "moisture flux test." With this test, the rate of moisture transport varied depending on the properties of the moisture sink used.

The third test measures moisture flow through a membrane when both sides are exposed to water. This represents the situation when water may penetrate through the exterior cladding to wet the outer surface of a WRB and moisture from inside the wall has wet the inner face at the same time.

Air entrapment within the microscopic pores of the WRB normally prevents water from passing through most membranes under most conditions. Water evaporates and diffuses through pores as a vapour. Even when the WRB pores are only partially filled with air, water vapour diffusion was still the dominant moisture transport mechanism.

Direct water movement takes place only when there is a continuous field of water across the WRB product and a high pressure on one side of the membrane. This high differential pressure does not occur in practice.

Testing confirmed that the small water head used in the tests had little influence on the amount of moisture transported through the membrane.

Based on tests of all Class C and P products, it was found that vapour flow was the dominant moisture transmission mechanism through the membranes for one-time wetting. The explanation for the dominance of vapour flow for these products is that the fine porous structure created by the fibrous matrix acted as a filter separating water molecules contained in the liquid from those contained in the vapour phase on the other side of the WRB, but allowed vapour to diffuse freely through the fibrous network.

In the case of liquid applied membranes (LA), these form films that do not have the same pore connectivity as C and P materials but have very low absorptivity and high resistance to liquid flow. LA membranes cannot be tested except as composites with other materials to which they are bonded.

Effect of surfactants

It is known that chemicals can leach out of materials such as OSB or stucco. As well, when sidings are pressure-sprayed when being washed, the liquid can penetrate the siding and wet the WRB behind.

The surfactants reduce the tension on the surface of a water droplet, making it smaller and easier to flow through small pores. The question is what the effect of surfactants is, and could it affect the performance of WRB materials?

A very significant effect of surfactants such as soap was observed. On the other hand, the soluble parts of wood extracts from some OSB materials were found to have a relatively small effect on the properties of the water on the pores or the WRB. However, this research also found that moisture transfer through Class C and Class P membranes using tap water or a one percent soap solution did not show a significant difference in moisture flow through them. This implies that the reduction in surface tension was still insufficient to break the meniscuses bridging the pores in these membranes, or that more research may be needed to determine that mix of compounds dissolved in the moisture that may penetrate the exterior cladding. The impact of a build-up of contaminants over time from repeated wetting at the WRB could also change these results.

Effect of penetrations

When nails and staples penetrate a WRB membrane, the moisture penetration increases by at least one order of magnitude compared to that without any penetrations. However, the moisture flow for an undisturbed product without the plywood substrate was much higher than when the plywood was present. In other words, when there is air on both sides of the membrane and the vapour pressure drive is high, more moisture can be driven through it compared with the liquid flow around the fastener shank into the substrate (without it being clamped by the head of the fastener).

The comparisons with and without fasteners, and with and without substrates simply reflect the reality that the rate of moisture flow through an assembly is controlled by the more resistive elements in it. However, more research is needed on whole assemblies to assess the effect of moisture entry at fasteners, especially given the stresses seen by membranes under field conditions.

Effects of weathering

Two batches of materials were aged for four months, one during summer, the other during winter. A small but not significant reduction in measured water vapour transmission was observed.

Some Class C and Class P membranes were also tested for airflow resistance before and after outdoor exposure. The results showed that the weathering did not significantly affect the air permeance. However, there was a significant

difference in moisture movement, with the weathered samples between these two cases using a liquid penetration test.

This finding shows that two test methods are needed to evaluate the performance of WRB under different conditions that are more closely aligned to field conditions.

This research has shown that the performance of class C and P membranes used for weather resistive barrier applications is quite different from many other porous materials used in construction.

In practice, WRB materials are intended to block rainwater from passing through them into the wall assembly. They achieve that aim because they have very small pores. In the tests, the pore size was not affected by aging, by weathering, or even by mechanical stretching of the WRB products. The air or vapour permeability was not much affected by weathering conditions expected during construction.

The use of soap or wood extract solutions also did not affect the air or vapour permeability for a one-time wetting because moisture movement through the materials was dominated by the vapour transfer phase. However, under some combinations of weathering in the presence of wood extracts and other solutes significant increases in water transmission resulted - one could observe water droplets passing through some membranes in a time span measured in minutes instead of days.

Use of the liquid penetration tests (water contact on both sides of the WRB) was found to discriminate between materials with local deficiencies and those materials where the negative wetting angle was neutralized by weathering. Some WRB products, which performed sufficiently well when assessed using existing test methods in product standards (for example, some types of PP products), experienced the onset of liquid flow within a few minutes.

To reduce the risk of water penetration, it is important to eliminate the possibility of water contact on both sides of the WRB for prolonged periods. This can be achieved by detailing assemblies that incorporate an air cavity on one side of the WRB. This measure is recommended for climatic conditions where the probability of water penetration is high.

Under moderate climatic conditions even a small air gap of 1 to 3 mm may be enough if it can be maintained. Such an air gap may be enough to allow free water drainage and, in combination with other measures, it may provide a substantial reduction in moisture loads acting on WRB materials. ✪

***Summary of Research on Water Resistive Barriers** for Canada Mortgage and Housing Corporation, by Dr. Mark Bomberg, Adjunct Professor, Department of Building, Civil and Environmental Engineering Concordia University and Don Onyoko, DMO Associates Limited*

Noise from Mechanical Equipment

As cities become denser and the distance between dwellings gets smaller, noise becomes more of an issue. Any unwanted sound, especially when it is loud enough to be noticed, is considered noise. What is music to one person can be noise to another, especially when they don't want to listen to it.

Sound is also subjective. Sometimes a change in the source of noise can be a problem in itself. For example, if a furnace in the home has been replaced, a different sound (even if it is not any louder) may now be heard and viewed negatively. Maybe the previous system had a louder blower, and when it is replaced by a new, very quiet unit the homeowner now hears the refrigerator that has always been there but was masked by the sound of the older equipment.

In some cases the sound the homeowner hears and finds objectionable can barely be heard by the contractor, but the contractor may hear something else that would drive him nuts. When dealing with noise problems, contractors should always make a point of hearing the sound the customer hears before doing anything.

It's worth remembering that sound is just a type of energy. For sound to become an issue there has to be a source of the noise, a receiver (i.e. a person's ear) and a path for the sound to travel. Without a path of travel the sound would be isolated to its source.

Sound energy can be transmitted through the structure as well as through the air. That is why airtight, energy efficient construction is also good at reducing outside noise penetration into the house.

Mechanical equipment creates its own challenges. Heating-only equipment, which usually is kept contained within a dwelling, seldom creates a problem when installed properly. However, the increased use of air conditioning in Canadian homes does become a noise concern because in split systems the compressor is located outside. When the exterior compressors are not installed correctly or properly maintained, they can be a major source of noise. These become more of an issue since they are mainly used during the summer when people spend a lot of time outdoors and may keep their windows open.

One source of the problem may be in the design of the equipment itself. North American manufacturers tend to focus more on the lowest initial cost than on the total quality of their equipment. High-efficiency air conditioning equipment that is also quiet can be designed and manufactured. They do it in Asia, but the equipment takes a bit more to make, and the price may have to be adjusted accordingly. In our market, the low initial cost tends to prevail over performance acoustic quality, although some improvements are on the way. Trane is one manufacturer that is working on new products that will reduce the sound from the outdoor units. They have also changed from a metal basepan to a composite one which prevents metal-on-metal vibration.

However, the equipment itself is not the only generator of unwanted noise. Proper installation practices need to be followed when installing equipment to reduce vibration issues as well as airborne noise concerns. Mechanical contractors need to pay close attention to installation practices. Builders may wish to keep these in mind, so that they can keep reviewing the work on their projects to reduce noise complaints. Some points to keep in mind include:

- In split systems, with inside and outside equipment, the refrigerant line between the inside and outside can contribute noise, especially when the lines have been pushed up against the drywall during construction or are resting on the top header of a wall. Similarly, refrigerant lines tightly strapped to floor joists or to duct work, without any acoustic sleeves, will generate some noise. Vertical refrigeration lines with high pressure points and forced fittings can also be a source of noise within the house.
- A faulty metering device at the air handler can cause the compressor to flood and have a high pitch to it.
- An improperly sized air handler can contribute to air noise in the ducts.
- Poor duct design is a noise source. If the supply plenum is too short or if the air handler unit dumps air into a main trunk at a 90 degree angle, especially if the duct is not acoustically lined, the system will generate noise. Anytime the air is subject to sudden changes in direction, it is possible to create noise. The higher the air velocity and the more drastic the change, the more pronounced the sound.
- Proper system design includes accurately calculated indoor blower capacity and duct air velocities.
- When the air handler has to be on an upper floor or in the attic, hanging the unit rather than letting it rest on the trusses or floor joists is one way to cut down on potential sound problems. Of course, having any mechanical equipment in the attic can be a concern unless the attic space is fully insulated and heated. It is never a good idea to place heating and cooling equipment and ductwork outside the heated envelope of the house.
- Another way to reduce noise is to keep the furnace or air handler up off the floor by placing the equipment on acoustic isolation foot pads that are now available.
- All equipment must be kept level. Any equipment that is out of plumb can become noisy.
- Coil and fan blades must be kept clean. A dirty coil creates high fan static similar to the thump of a helicopter and dirty fan blades unbalances the fan and creates vibration.
- Refrigerant charge is critical to sound. Over or undercharging a system can lead to unwanted noise. ✪

Controlling Equipment Noise

Occasionally, even properly installed exterior equipment may still need to have a noise barrier built to reduce excessive noise. There are limits to what can be done to reduce noise, but any reduction may go a long way to reducing the source of complaints. Most noise issues are driven by complaints, and in most cases municipal noise measurements are taken at the property line adjacent to the problem equipment, not at the point at which the noise is received.

Controlling equipment noise can be done in several ways:

Relocate the equipment. Sometimes moving the equipment to another location on the property may solve noise problems.

Slow down the equipment. For exterior compressors, the fan is a major noise source. If the fan speed can be reduced, it will substantially reduce noise. A 20% reduction in fan speed can reduce sound levels by about 5 decibels. Slower fan speeds may also result in less cycling, and when the equipment is running more continuously, there is less perceived annoyance, since the starting and stopping of equipment generates its own noises.

Replace with quieter equipment.

Install a manufacturer's noise control package. Most manufacturers should have sound abatement packages, even if they don't promote them aggressively.

Noise enclosure. A barrier adjacent to the equipment can be useful providing it is designed and installed properly, avoiding reflecting surfaces, which can simply bounce the sound. Typically, between 5-10 decibels of attenuation can be achieved.

A good sound barrier must block a line of sight from the equipment to the receiver, not allowing the noise simply to be bounced onto adjacent hard surfaces or around the end of the barrier, and must still allow for the proper functioning of the equipment.

A good sound barrier must be solid: ½ inch plywood is good and must be lined with a good sound absorbing material. The best sound absorbers are glass fibre materials, such as rigid fibreglass or rock wool boards. ☼

Thanks to Kim Cairns of National Energy Equipment Inc. and Douglas Whicker, a North Vancouver acoustical consultant (www.bkla.com) for material on which this piece was prepared.

Sound

Sound is defined as any pressure variation that the human ear can detect. The number of oscillations per second is the frequency, measured in hertz (Hz). Thunder has a low frequency, while a whistle has a high frequency. Human hearing ranges from about 20 Hz to 20,000 Hz, although the range decreases with the hearer's age.

The lowest notes of an organ, bass, tuba, and other instruments are in the range of 20 to 80 Hz.

Most music and human speech is in the range of 250 to 6,000 Hz.

Frequencies are an important component in the perception of noise and loudness.

Sound levels depend not only on the amount of sound pressure generated but also on the distance from their source.

Sound pressure is measured in decibels, which is a logarithmic scale. The smallest change a person can detect is a difference of about 3 decibels. 10 decibels represents a doubling in the apparent loudness of a noise.

10th Canadian Building Science & Technology Conference

National Building Envelope Council
May 12, 13, 2005, Ottawa.

The conference will build on the successful series of Canadian Building Science & Technology Conferences over the past twenty years. It offers a venue for building scientists, architects, engineers, property managers, contractors and others in the building construction industry to present and share ideas on building, renovating and repairing better buildings. More than 400 national, and international, experts on building science are expected to participate in the two full days of presentations and discussions focussing on practical applications, case studies and fundamental research.

The 10th Conference is a "must" for those with an interest in building science, building envelope, construction, renovations and repairs.

For details: *www.nbec.net/conference*

Geothermal Energy as a "Green" Heating Source

by Richard Kadulski

Geothermal heating systems seem to have caught the public's imagination. They are touted as today's great environmentally appropriate heating option. Geothermal, or ground source, heat pumps are very efficient ways to provide space heating and cooling of buildings.

We don't want to discourage their application. However, there is a great misconception that going geothermal is the best green solution to meeting space heating and hot water heating energy demand. And worse, many projects are labelled as "green" construction merely because they have installed a ground source heat pump.

Too often it is looked at in isolation from the rest of the construction. The great benefit of geothermal is that for each 1 kWh of energy you put in, you get 3 kWh or so out of the system - that is its great efficiency advantage (300+% efficient! as the marketers would put it). But you still have to put in the 1 kWh.

If the building has a large heat load, you get the benefit of savings but there is still the input demand that needs to be provided for. Geothermal systems should be sized after all possible conservation measures are implemented - this means all the passive elements that will reduce heat loads: better insulation levels over the entire building envelope (including full basement insulation), high performance windows, solar orientation wherever possible, and airtight construction. As a minimum, the construction specifications for a home should meet the R-2000 standard for energy consumption.

Only after all the passive energy efficiency measures have been taken should you size a geothermal (or any other heating) system. This will mean that the system size will be reduced, making it more cost effective.

What most people don't appreciate is that, unlike conventional gas or oil furnaces, each increment of heat output from a heat pump system has a cost increment associated with it. If you double the size of a high-efficiency gas furnace, the cost increment will be small, but not double. However, for a heat pump, each increment of increased size has a significant cost associated with it, so it actually pays to have a smaller heat pump more closely sized to the demand. This is especially significant for geothermal systems because each increment of size requires not only a larger heat pump unit, but also more piping in the ground, and that can be expensive to install. In the Vancouver area, a budgeting rule of thumb is that each ton of demand (12,000 BTU/hr) requires one well, and drilling costs alone are about $1200 per well. On the West Coast, with its mild climate, it is actually possible to design homes that require no furnace.

With extremely small heat loads, one then needs to question what the best source of added heat required is. In some cases it will be appropriate to use geothermal, but not always. Geothermal systems are especially beneficial when there are summer cooling loads - as happens in commercial and institutional environments and in some parts of the country. Many parts of Canada, including the West Coast, simply have no need for cooling if the home is properly designed. The climate simply does not have a significant enough cooling load to justify air conditioning to the degree we see being installed.

One aspect that is not always discussed when geothermal systems are considered, especially if there is not much of a summer cooling load which discharges excess heat from the house back into the ground, is the seasonal performance. With a heating-only load, the heat pump will work mostly one way - taking heat from the ground into the building, which chills the ground. Unless the ground temperature is able to warm up seasonally, the system effectiveness declines, and there is a danger of frost building up in the ground. In extreme cases, small permafrost patches could develop.

Horizontal ground loops can benefit from solar heat gains over the summer. Ground loops in wet soil, or soils where there is underground water flow, have a good performance potential because of the thermal conductivity of water.

In parts of Central Canada, and a few coastal locations, especially in west-facing waterfront homes, there is excess heat in the summer which may require cooling. Although the West Coast

has no cooling loads, we see cooling being installed almost as a norm in new homes throughout the Vancouver and Victoria areas. That's not to say that there is no place for geothermal systems in locations without cooling loads, because there are still many good applications for geothermal, but they need to be carefully evaluated. It's important not to jump on the technology bandwagon simply because it looks good, without considering the other aspects of building design and energy loads.

Too many people are jumping on the green bandwagon with geothermal heat pumps, without putting them in context. Just installing geothermal is not "green" unless all the other conservation aspects are dealt with.☼

Fire Resistance of Gypsum Board

Fire resistance is an important aspect of construction. Gypsum board is a key material used in all types of construction assemblies for finished surfaces and as a fire resistant finish. One or more layers of gypsum board can provide up to 90% protection against fire. The greater the density of the gypsum board, the greater the fire resistance.

The fire resistance of gypsum board is due to the board's makeup. It is made from calcium sulfate, a mineral crystal formed during the dinosaur age and found in all parts of the world. The crystals contain water molecules, and it is this water that gives gypsum board its fire resistance.

As heat is applied to the gypsum board, it starts to dehydrate by driving off the water contained in its chemical structure. The dehydration begins at about 80°C (176°F) and the heat energy goes into driving off water (turning it into water vapour), not into increasing the temperature of the mineral. Only when all the water has been removed, will the temperature of the board increase.

This ability of gypsum to remain at relatively low temperatures, even when a flame is applied directly to it for a short period of time gives drywall its fire resistance to the wood frame construction. Even with a fire directly on a sheet of drywall, the wood frame behind it will remain at a relatively low temperature until too much water has been lost from the gypsum, preventing the destruction of the wood and the collapse of the structure. Partially dehydrated gypsum, when the heat source is removed, has can reabsorb water.

For most construction assemblies the critical characteristic that determines the fire resistance is the delay in heat penetration provided by the evaporation of the water contained in the gypsum board. For practical purposes, the density of the board provides an indication of how much water is contained within the board, and hence its fire resistance. Crack-resistance and material shrinkage also play an important role in determining how well drywall assemblies are able to provide fire protection.

Traditionally, the gypsum board material used in fire-rated assemblies has been designated as Type X gypsum board, and can provide up to 90 minutes of fire resistance protection for building assemblies. The classification is based on the product simply meeting or exceeding a designated fire-resisting threshold established using a standard test method such as ASTM C 36/ 36M - 031. This sets a minimum standard, but does not fully take into account the variability in the material.

A multi-year study at the National Research Council of Canada (NRCC) looked at the fire resistance and acoustical performance of a range of wall and floor assemblies. The studies found that there is a wide range of density in the Type X products. This variation occurs both between products of different manufacturers and within an individual manufacturer. This wide variation in the materials could be a concern in how well construction using the materials actually performs. It also points to an area where more work is going to have to be done.

The variation in board density within and between manufacturers of Type X gypsum board was fairly large. Based on a sampling of Type X sheets purchased from local suppliers, they found the density of 12.5 mm (½ inch) sheets varied from 759 to 811 kg/m³, while 15.8 mm (5/8 inch) type X board varied from 687 to 750 kg/m³.

Although board density is only one of the factors, it is probably the key factor that defines the delay in the failure of the gypsum when subjected to a fire source. If material from one

manufacturer were to be used to establish the performance of an assembly, using products made by another manufacturer could result in a 7 to 9% lower level of performance depending on which products were used.

As building and fire codes move towards a performance-based approach, rather than simple prescriptive requirements, the ability for designers to have a fairly high level of confidence in the performance of the specified material becomes more important. Designers, builders and fire officials have to clearly understand how best to be able to calculate the fire resistance with confidence. They will need more precise characterization of the gypsum board material itself and not as a part of a building assembly as has been the practice.

With the increased use of engineered fire resistant designs, it is important that designers have reliable information on the performance of materials that play a critical role in their designs. Products and materials with a high degree of variability associated with their performance will result in the designers having to over design their systems to compensate for the uncertainty and losing many of the benefits that could come from a performance design approach.☼

Impact of the Variability of Type X Gypsum Board Russ Thomas, Mohamed Sultan and John Latour NRCC-47635, Fire Research, National Research Council of Canada. A version of this paper was published in the proceedings of the Fire and Materials Conference, San Francisco, Jan. 31-Feb. 2, 2005

Letters to the Editor

I am a fan of Solplan Review magazine. I read each issue cover to cover, and file them away as reference material.

I am involved with residential window sales and renovation advice, so I find articles on humidity, insulation, ventilation, mould remediation, and high performance glazing to be very interesting.

We all look to the future of better insulated, better ventilated, efficient and comfortable homes wherever greater R-values and lower energy costs are achieved. Building code changes force us to design better products, methods, and systems all the time.

I believe, however, that the residential window has been overlooked. Why is it that we have raised the standards for wall structures and heating/ventilation systems but we still allow sealed, double-glazed window units with R-values of not much more than 2, and minimum A ratings for air leakage. Why are these still considered acceptable? I believe that the minimum acceptable residential window today should carry an A3 rating and incorporate soft coat Low E. What is the point of building a highly insulated wall and installing an inefficient window just to let the heat out?

Harold Bream
Terrace, BC

Re: High Performance Houses (Solplan Review No. 120, January 2005)

I fear that the insulation values for the UK you quoted are wishful thinking. It may not be that good in Ireland either. I think the numbers for Swiss and Danish housing can be relied on, but Switzerland and Denmark have a different culture where workers are trained for years before they're allowed to do construction work without supervision.

Thermal bridging is excluded from the UK and Irish figures. The real R-Values (one must use this for heat loss calculations) is worse than is currently quoted. A recent study for the government found that in a sample of new UK dwellings more than 50% did not meet the current energy regulations. This survey of as-built homes did not check actual wall or floor insulation, as these are covered up by the time a house is finished and occupied.

So, I fear the grass here and in Ireland seems a little greener than it really is!

The air leakage of a randomly-chosen new UK dwelling would probably be closer to around 12 m³/m²hr at 50 Pa (equivalent to about 12 air changes per hour on a small detached house). However, based on a 1999 database assembled by the BRE (Building Research Establishment) the assumption was that the mean for modern houses was between 8 and 10 ac/h.

The problem is that there has been very little air testing done on small buildings. The few tests that have been done have not been random. Of the tests that have been done most are done at the request of a specific developer or owner. The fact that the person asking for an air test is interested enough in the result to pay up to £400 for a test makes these rather unusual, and it

suggests that on average only the better buildings get tested. Some of these results then get included in samples, without enough checking of whether these are sufficiently representative of the average housing stock.

David Olivier, Energy Advisory Associates
Herefordshire, UK

We appreciate that UK energy performance construction standards may still be quite low. Often, when new standards are introduced or existing ones revised, decisions are made based with the best of intentions and great optimism, and there always seems to be a gap between desired performance and reality on the job site.

We did not mean to imply that the high energy standards are actually in place today. As we mentioned, it may be a while before builders are able to do the job properly and deliver housing to the standards being discussed. In Canada it has taken us many years to improve the energy performance of standard houses and there is still a long way further we can go to improve them. The best, most efficient homes, such as R-2000 homes, still represent the leading edge and a small segment of the market, although they point the way for the industry at large.

In our item, we wanted to point out that serious moves are being made to improve the performance standards in Europe. In the UK it seems a real effort is being made to search for ways to incorporate higher performance standards. How quickly these high standards are achievable in practice is another issue. In Canada, on the other hand, we seem to be afraid to come to grips with the changes we must make in order to stop the degradation of the global environment. Ed.

Re: Basement Floor Insulation (Solplan Review No 120, January 2005)

Although the arrival of Solplan always brings some joy, I can't always sit down to read it cover to cover immediately. Sometimes the pragmatics of earning a living and answering client calls must prevail. I just got down to the January issue today and I have a couple of comments on the Basement Floor Insulation article.

It was stated that expanded polystyrene (bead board) could be used under a poured concrete slab, although it would have to be thicker to provide the same insulation value as extruded polystyrene. It is my understanding that only type IV extruded polystyrene is approved for this kind of installation as other products do not have the density to support the weight of the concrete. Also, expanded polystyrene is not approved for direct earth burial as it can be impacted by water/moisture in the soil.

An important issue with heating was not discussed. Cold air is heavier than warm air. Any relatively cold air entering the building, whether as a result of ventilation, infiltration or someone opening the door, will head through the shortest path for the basement floor. It will displace the warmer air there and collect in a cold pool on the floor. Most return air grilles for a furnace are located on the main floor in a hallway or behind a chesterfield. This location is about as far from the pool of cold air as possible. A cold air return from the basement floor to the furnace is just as essential to a warm, comfortable, fungus-free basement as insulation and dampproofing.

Wayne Wilkinson
Whitehorse, Yukon

Your understanding of the insulation requirements under concrete slabs is widely shared. The categorization of rigid foam boards acceptable for use below grade was eliminated a number of years ago. Under the building code, all rigid foam board insulation products are now acceptable for use underground. The change was made after studies showed that bead board does not absorb unacceptable amounts of water. However, the lighter density boards have a lower R-value per inch thickness than the extruded polystyrene products, so you need to use thicker boards when a minimum insulation value is desired.

You are right to express some concern about the carrying capacity of the materials. You would not place the foam insulation under the foundation at point loads, but otherwise it is acceptable, as the loading of a slab-on-grade is actually quite small. The normal design live load for a residential floor is considered to be about 40 pounds per square foot, and a 3 inch concrete slab is about 35 pounds per square foot, or about 0.52 pounds per square inch. The compressive strength of type I expanded polystyrene is about 10 psi.

Some manufacturers of expanded polystyrene even offer a value added product that is a bead board that is grooved to accept radiant heating system piping for use under concrete slab floors.

You make a good point about the need for cold air returns in the basement. Your comment also points out the importance for a proper design to be done for heating systems. It also raises the question whether or not there is a continuously operating fan or not. The continuous operation of the furnace fan will not eliminate the pooling of the cold air, but the will help recirculate the air within the house, and may reduce the effect of temperature stratification in the house.

However, I would suggest that if there is a lot of cold air pooling in the basement, the result of air infiltration, it may be an indication that the house is not as airtight as it could be. Significant temperature stratification is an indication of the movement of buoyant warm air to the upper portion of the house, where it leaks out through air leakage paths in the ceiling and upper portions, to be replaced by heavier cold air which initially falls to the lowest level in the house. Ed.

Asbestos Hazards in Demolition, Renovation, and Salvage

Asbestos is a strong, fire-resistant mineral fibre. In the past, asbestos was used as insulation against heat or noise and for fire protection. It was also added to materials such as cement and plaster to give them more structural strength.

Although useful for many applications, asbestos is a hazardous material. We've known about its hazards for some time, and it now has largely been phased out of use. However, the consequences of the use of asbestos in the past are still with us, and asbestos does impact workers in the construction industry. The Workers Compensation Board of BC has indicated that between 1995 and 2003, 120 of 258 deaths in the BC construction industry were from asbestos-related diseases.

The most vulnerable part of our industry is the renovation sector. Demolition or renovation of houses containing asbestos products can release asbestos fibres, which are extremely fine and can stay in the air for hours. Unprotected workers exposed to asbestos-contaminated air can breathe in the fibres which may cause serious health problems — including lung disease and cancer.

Until the late 1980s, more than 3,000 products containing asbestos were used in house construction. When demolishing older houses there is a high probability of encountering asbestos-containing materials that may release asbestos fibres. Some of the locations in the house where asbestos was commonly used in its construction are noted on the drawing.

Employers are responsible for ensuring the health and safety of all their workers and of any other workers present at the workplace. Employers are also responsible for protecting the public.

The WCB has specific regulations that must be followed. Regulations and good information pieces are posted on the WCB website at *www.worksafebc.com*. Their booklet *Safe Work Practices for Handling Asbestos* is an excellent resource.

Before work begins on the demolition, renovation, or salvage of buildings or structures, builders should ensure that an assessment has been made as to whether there is any asbestos on the job site and how it will be dealt with. All asbestos-containing material that is friable (i.e. easily crumbled or powdered by hand pressure) must be removed and disposed of by trained and qualified workers before demolition, renovation, or salvage work is started.

Before renovation starts is also a good time to survey the presence of other toxic or unsafe products. Older buildings are likely to contain lead paints that also need special care when being handled.

Asbestos survey and removal companies can be found in the Yellow Pages under Asbestos Abatement & Removal, Health & Safety Consultants, or Environmental Consultants.

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Technical Research Committee News

Canadian Home Builders' Association

National Building Code Update

The revised edition of the National Building Code is scheduled for release in September 2005.

This revision is significant not only because it has been almost ten years since the last revisions were made, but also because the structure of the code has been changed substantially. The core of the document has been redrafted as an objective-based code. Part B of the code will be an updated version of the present code, and will contain "deemed to comply" requirements for those not willing or able to use the objective code requirements.

Because this revision is a radical departure from the current format of the code, there will likely be a period of confusion as users try to determine how best to use and administer the new code. The new format should make it easier to deal with alternative or innovative construction products and techniques. However, users will still have to prepare appropriate documentation showing how the new approach may meet the stated objectives of the code. All code users will need to be briefed on the intent of the code, how it is intended to work, and how to implement the code.

The Codes Centre has indicated that they will be doing a series of presentations across the country to explain the technical changes made in the code. These will largely focus on Part B of the code, which will resemble the present code document. The bigger challenge will be with the core code document which has the objective statements. Unfortunately, the federal provincial committee that is developing training materials is only focussing on a training package aimed at building officials. They have no plans to develop tools for builders or professionals to help them with the new code format, which could be a problem for all participants in the industry. CHBA has been pressing to have training materials for all users, not just building officials.

CMHC has offered to support the development of builder training materials on the effective use of the Objective-based Code.

Residential Ventilation Requirements

The new code edition will include changes to the ventilation requirements. CMHC plans to prepare a guide on how to comply with the ventilation requirements in the 2005 NBC. It is hoped that the new ventilation guide will be ready when the new Code is released in the Fall of 2005.

Code Interpretations

A challenge we all face is that when an interpretation of code requirements is done, or alternative solutions are decided on in a jurisdiction, the information is not always distributed to other users. Although equivalencies are unique, and cannot be applied across the board, there are many instances where an equivalency assessment made in one jurisdiction could help other building officials and code users when similar conditions occur in other locations. That is why CHBA is assessing provincial government web sites that provide information on alternative solutions to code requirements. It is hoped that it may be possible to put together a web-based database by simply linking to the various locations where decisions have been posted.

Canadian Electrical Code

The Canadian Electrical Code (CEC) was first published 78 years ago by the Canadian Standards Association (CSA) to improve safety and bring order to the new technology of electricity. By 1930 it was universally adopted by provincial governments throughout Canada. The Electrical Code functions as a model regulation, which is made mandatory when adopted by local jurisdictions having authority.

Recently, concerns have been expressed about the process by which changes are made to the electrical code. Electrical code changes may have far reaching impacts on the housing industry, but builders and many users don't hear about the changes until after they have been incorporated into the code.

CHBA has prepared a discussion paper on the Canadian Electrical Code. The paper does not deal with specific requirements of any current or proposed changes, but rather looks only at policy and procedure issues. The paper makes a number of recommendations.

- As a model regulation, the CEC should meet the same criteria for regulatory efficiency as other regulations.
- Participation of affected federal, provincial and territorial departments at a policy level, including housing should be encouraged, perhaps through the National Public Safety Advisory Committee.
- All requirements and proposed changes should have to meet basic tests. Proponents should be required to measure the impact on typical housing, including entry level units.
- The cumulative impact of proposed changes should be determined for all changes.
- Recent suggestions to increase transparency in the drafting of the document should be continued.
- An Objective-based version of the CEC should be prepared.

For more information on the paper, contact Don Johnston at the TRC.

The Technical Research Committee (TRC) is the industry's forum for the exchange of information on research and development in the housing sector.

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2005 Building Science Insight Seminars

The focus for this year's seminar series will be on roofing, primarily low slope ("flat") roofs. In the past, there were few choices of roofing materials. Roofing was labour intensive and labour was inexpensive. Today new roofing materials and systems are used for water shedding or waterproof assemblies. The choice can be overwhelming and confusing. This one-day seminar will provide key technical information on the evaluation, performance, maintenance and durability of roofing materials and systems to help users make the right decisions for roofing projects.

Information:
http://irc.nrc-cnrc.gc.ca/bsi/2005/index_e.html

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Procedures for abatement of asbestos-containing material during house and building demolition/renovation are noted in the Guidelines Part 6 (available on the WCB website at *http://regulation.healthandsafetycentre.org/s/GuidelinePart6.asp*). This includes a table that provides guidance for removal of various asbestos-containing materials, such as taped and mudded drywall, textured coated ceilings, asbestos cement shingles, roofing, or siding, tape or paper covering forced air ductwork, vinyl asbestos tile and sheet flooring, and asphalt roofing material. ☼

Information:
www.worksafebc.com
WCB Health & Safety Centre for Construction
http:/construction.healthandsafetycentre.org/s/Home.asp
http://regulation.healthandsafetycentre.org/s/GuidelinePart6.asp
Phone: 1 866 319-9704 Fax: 604 232-9703,
E-mail: *customer.service@worksafebcstore.com*

Affordable Comfort 2005

May 16 – 21, 2005
Indianapolis, IN
This is the premier American venue promoting residential building performance, energy efficiency, comfort, health, and safety in home retrofit, new construction, and renovation. Information: *www.affordablecomfort.org*
tel.: 800-344-4866, ext 10 fax: 724-627-5226

Energy Answers

Rob Dumont

What do you consider to be the top five Energy Efficient Homes built in Canada?

Mark Twain said that "It is not best that we should all think alike; it is a difference of opinion that makes horse races." The following are my own opinions. Others would bet on different horses.

My criteria for selection of the top five were as follows:

1. Breakthrough concepts
2. Deep green ideas
3. Widely publicized
4. Clearly more efficient than other homes of that era

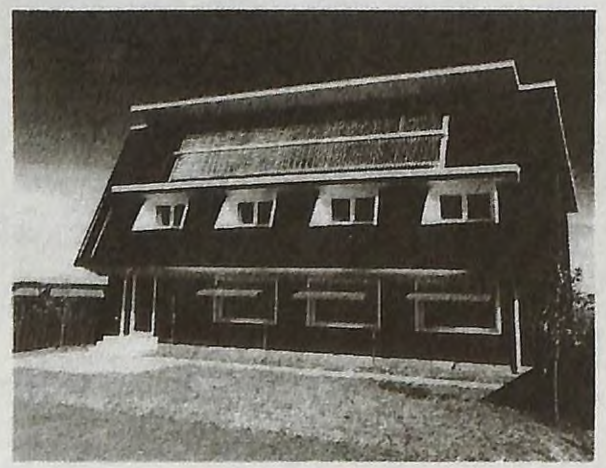
As I was involved with one of the houses, I rank myself as a participant as well as an observer. Thus, my opinions are definitely biased.

Here are my picks:

1. Provident House, King City, Ontario.

This house, built in 1976, was a brainchild of Frank Hooper, Professor at the University of Toronto. It was designed for 100% active solar space heating using a 67 square metre active solar system and a 272 cubic metre water storage tank. I rank this building in the top five because of its dramatic performance goal. It took a lot of guts at that time to design a building for Canada's climate that could be 100% space-heated by the sun.

2. Saskatchewan Conservation House, Regina, Saskatchewan.



This house, built in 1977, had several key persons involved. Bob Besant of the University of Saskatchewan was heavily involved in the design of the active solar system, the air-to-air heat exchanger, the grey water heat recovery unit, and the insulation system. Harold Orr of the National Research Council did some outstanding work with the air tightness details for the building. (It came in at 1.3 air changes per hour at 50 pascals on its first test and was very likely the tightest building in Canada at that time. It was later discovered that the motorized shutters for the south windows were a substantial source of air leakage. Once these holes were patched, the air tightness came in at 0.8 air changes per hour at 50 pascals– a particularly outstanding air tightness number, even when judged by today's standards.) David Eyre of the Saskatchewan Research Council was the manager who made the project happen. I was a grad student at the University of Saskatchewan at the time, and helped out with a number of things including the grey water heat exchanger and the house monitoring.

This house had some firsts for Canada: the first residential air-to-air heat exchanger using plastic heat transfer surfaces, the first well-sealed house, and the first greywater heat exchanger.

3. Brampton Advanced House, Brampton, Ontario

This house, built in 1989, was designed by Elizabeth White and Greg Allen. It used an integrated heat pump that was capable of space heating, water heating and ventilation. Very high insulation levels were used for southern Ontario. It was one of the first to very aggressively address lighting and appliance energy consumption.

4. Waterloo Green Home, Waterloo, Ontario

This house was one of 10 demonstration houses built as part of the Canadian Advanced Houses Field Trials. Completed in 1993, this house was, in my opinion, the most innovative of the 10 houses. An enjoyable book *Green Home: Planning and Building the Environmentally Advanced House* by Wayne Grady documents the design and construction. Steve Carpenter and John Kokko of Enermodal Engineering were key design people involved with the project.

5. Toronto Healthy House, Toronto, Ontario

This 1994 duplex showcased a large number of renewable energy and conservation technologies, along with a very aggressive water efficiency program including rooftop capture, and water re-use. Chris Ives of CMHC was a key innovator.

All of the above houses represented significant advances on conventional construction. The next logical step in this chain of innovation would be to develop a house that was completely autonomous in its energy and water supply. A substantial barrier is the current relatively high cost of photovoltaic panels. Very aggressive electricity conservation measures would no doubt help in achieving such a challenging target.☼

BC Removes Sales Tax on Residential Furnaces, Boilers and Heat Pumps

The recent BC budget has exempted energy efficient residential furnaces, boilers and heat pumps from the provincial sales tax if they are purchased for a residence between February 16, 2005, and April 1, 2007. This is effectively an immediate 7% price reduction.

To qualify, gas-fired forced-air furnaces, boilers, air-source heat pumps and ground-source heat pumps must be listed as "Energy Star Qualified" by the Office of Energy Efficiency, Natural Resources Canada. Oil-fired furnaces that have a Seasonal Energy Utilization Efficiency (SEUE) rating of at least 85% also qualify for exemption from PST. The SEUE rating was established under the federal government's Energy Efficiency Act.

For heat pumps, the exemption includes all major components, including piping, refrigerant solutions circulated within closed-loop heat pump systems, heat pump thermostats, and the heat pump itself (for example, evaporator, compressor, condenser, coils, heat exchanger, valves, fans, blowers). The exemption does not include heat distribution systems such as duct work used to circulate air in a house, generic thermostats, or supplementary heating systems that are not integral to a heat pump system.

A listing of the furnaces, boilers and heat pumps that are Energy Star Qualified may be found by following the links at the Consumer Taxation Branch Web site at *www.rev.gov.bc.ca/ctb*. This list provides information on the brand names and model numbers for qualifying items.☼

NRC-CNRC

NRC/IRC's Material Emissions Study Yielding Results

By John Burrows and Doyun Won

The heightened interest in indoor air quality means more attention is being paid to emissions from building materials and furnishings, especially volatile organic compounds (VOCs). VOCs are emitted from many consumer products such as cleaning solvents, aerosols, and dry cleaned goods. They are also present in varying degrees in building materials like paints, coatings, sealants, carpets and adhesives.

While the adverse nature of VOCs has been known for some time, it has been difficult to accurately measure their concentrations, or to understand their effects on health. This meant there was little guidance that could be given to builders and designers to help them select materials that reduce the exposure of occupants to potentially harmful emissions.

Recognizing these problems, NRC's Institute for Research in Construction partnered with industry and government in the late 1990s to launch a comprehensive research project on material emissions. The study had two main objectives. The first was to provide the building industry with tools for assessing the contribution of a given building product, material or furnishing to a given indoor VOC concentration, with a view to helping builders and designers make "healthy" selections. The second objective was to provide product manufacturers with much better knowledge about the VOC emission characteristics of their products and in so doing, establish a baseline for reducing emissions.

Phase I of the project saw the researchers first develop test standards so that emissions from building materials and furnishings could be measured consistently. They then used the test methods to determine the quantity and composition of emissions for 48 commonly used building materials. This test information became the starting point for a database of material emissions that building designers could use to make educated choices for building materials and furnishings. Based on the materials emissions database, a software package called MEDB-IAQ was developed to predict the chemical concentrations in a room for given materials and ventilation conditions. All of this work in Phase I was a good start, but obviously the resulting database was small relative to the many building materials and furnishings available to building and interior designers.

John Burrows is an Ottawa-based consultant and technical writer.
Dr. Doyun Won is a Research Officer with the Indoor Environment program of NRC's Institute for Research in Construction.
For more information on the study, contact Dr. Won at 1-613-993-9538; Doyon.won@nrc-cnrc.gc.ca

Phase II was initiated in 2000 with several objectives:

a) increase the number of building materials and chemical compounds in the database

b) make the software easier to use

c) advance the development of indoor air quality guidelines for office and residential buildings

d) make it easier for investigators to diagnose possible IAQ problems in buildings

e) help designers assess trade-offs between ventilation and control of the emission source.

Phase II has proceeded according to plan and has produced several products that will make it easier for building designers and builders to design for lower concentrations of emissions. The database has been expanded and now contains more than 2,600 combinations of materials and chemicals that can be accessed by the air quality simulation software. The software has been improved and is capable of predicting the impacts of material selections and ventilation strategies on indoor air quality. The program can be used to determine whether the user's choice of materials and ventilation strategies can meet a specific air quality guideline and/or how long it will take for the concentration to fall below that guideline. (A Phase II report summarizes indoor air quality guidelines for specific chemicals.) The software will be available on the IRC website for downloading in late 2005.

The project identified 90 VOCs emitted from building materials, about half of which are known to be potentially harmful to human health. Additional chemicals will be identified as new building products are introduced and as more is learned about the health effects of VOC concentrations. Although it is known that VOCs adversely affect health, much more research is needed to determine safe exposure levels for each type of chemical, taking into account the variations in people's sensitivity to VOCs.

From the Phase II work also came a best practice guide for managing VOCs and indoor air quality in office buildings, and applicable to a lesser extent to residential and other types of buildings. It will help building owners, property managers, and building operators avoid, minimize or rectify indoor air quality problems. It will also serve as a reference for daily duties and for the training of building personnel. The guide includes information on VOCs and their sources, causes of occupant complaints, emissions from office furniture, strategies for improving indoor air quality, diagnostic techniques for identifying potential IAQ and ventilation problems, and the balancing of ventilation and energy use. The guide is currently in a report format and is expected to be available in a manual format in late 2005.

The completion of Phase II of the materials emissions project significantly increases the store of knowledge about emissions from building materials and furnishings. It also enhances the ability of the building industry to manage indoor air quality. One area that requires further examination is health effects. In the meantime, the information from Phases I and II can be used by building designers and builders to keep VOC emissions from building materials and furnishings as low as possible. In addition, IRC will continue to add to the materials emission database as new products and building techniques evolve. ☼

Phase II of this project is being supported by:
- Public Works and Government Services Canada
- Natural Resources Canada
- Canada Mortgage and Housing Corporation
- Health Canada